EARTH SCIENCE ENTERPRISE TECHNOLOGY STRATEGY

Strategic Goal: The strategic goal of the Earth Science Enterprise technology investment is to:

> ***Plan, develop, and infuse advanced technologies to enable scientific measurements and serve applications priorities***

Strategic Management Approach: The Earth Science Enterprise conducts a consolidated advanced technology program, external to ongoing projects, that relies on a direct linkage between science and technology. Under the model of "Science/Applications Needs → Technology Options → Measurement Capability → Enabling Science/Applications" (Figure 1), the priorities of technology development and in-space validation are determined based on Enterprise needs and the technology investment is optimized at the Enterprise level.

The consolidated ESE technology program also serves as the focal point for ESE to articulate its technology capability needs to a wide science/technology/ applications community, and to partner and collaborate with other technology development and validation programs within and outside of NASA to maximize the return on technology investment by minimizing duplication, expanding the future technology solution space, leveraging existing efforts and resources, and enabling technology infusion into flight missions and operational systems.

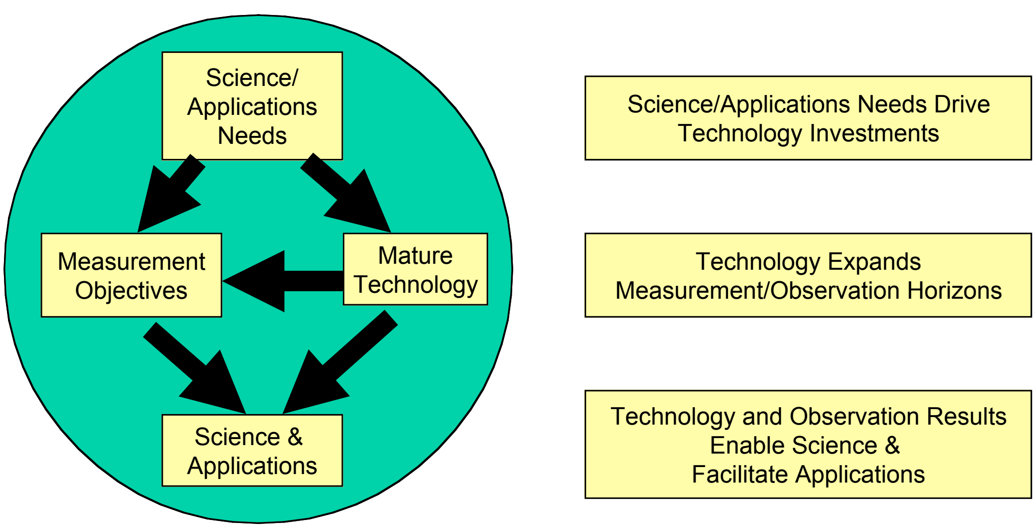

Figure 1. Technology driven by science/applications to provide enabling tools

The Earth Science Enterprise adopts the following approaches in conducting its advanced technology investments:

- **<u>Plan Technology Investment Based on Enterprise Needs</u>**
  The goal of ESE technology planning is to ensure the alignment of technology development with Enterprise priorities and to facilitate the infusion of advanced technology products, the ESE technology program documents and validates Earth system science and applications needs. The technology capability needs and the implementation options to address these ESE science/applications needs are analyzed through the various studies including feasibility, option and trade, system and architecture studies, and etc. Workshops are held periodically for planning purposes that include technology projection and roadmapping.

  Technology investment is selected through open solicitations based on gaps between the current investment portfolio and the documented Enterprise needs. The ESE technology program addresses the whole range of technology capability needs of the Enterprise from observations, information systems, and computing technologies.

- **<u>Develop Advanced Technologies to Mature Levels</u>**
  The goal of ESE technology development management is to mature promising technology concepts to a technology readiness level (TRL) acceptable for infusion. The TRL advancement is demonstrated through lab, field, airborne and, when necessary, in-space validation experiments and testing to mitigate the risk associated with the initial operational use of an advanced technology.

  The ESE technology investment portfolio is balanced in a way that not only strikes a balance across the different technology thrusts and different platforms, but also supplies advanced technology solutions in a time-continuous manner to meet the Enterprise's near-, mid-, and far-term needs.

  Advanced technology concepts at low TRLs provide the seed corn for potential revolutionary approaches to meet the Enterprise' long-term needs. The emphasis of managing low-TRL technology concepts is to expand the technology solution space of the future by encouraging out-of-the-box thinking that may revolutionize how ESE execute its future missions. Although the ESE technology program funds low-TRL advanced technology concepts through the Advanced Technology Initiative Project, the core strategy of ESE for fostering advanced technology concepts at low TRLs is to leverage other agency-wide advanced concepts programs such as the NASA Institute of Advanced Concepts, the Pioneering Revolutionary Technology Program, the Small Business Innovative Research Program, and the NASA Exploration Team, etc. ESE provides and promotes its science/applications needs to these advanced concepts programs to foster promising advanced concepts. As the advanced technology concepts further develop through these agency-wide programs, ESE selects and funds the more promising and relevant ones for continuing development into mid-TRL stage.

  Mid-, to long-term Enterprise technology needs are funded through the focused ESE technology projects including the Instrument Incubator Project, the

Advanced Information System Technology Project, the Computing Technology Project, and the New Millennium Program. As the technology concepts advance to the mid-TRL from the low-TRL, the resources requirement for the continuing development increases significantly. The emphasis of managing the mid-TRL technology development, therefore, is to ensure only promising technologies aligned with the Enterprise needs are funded. Since another order of magnitude increase of resources is generally needed for high-TRL technology developments, the technology candidates for high-TRL development have to be high-priority, and the managing focus is to eliminate the final infusion barriers into missions and operational systems.

- **Infuse Advanced Technologies to Enable and Enhance Future Capabilities**
  It is well recognized that infusion of new technology into future science missions and operational systems is a challenge. The ESE technology program adopts an end-to-end approach to facilitate technology infusion. Investment planning is conducted with the help of the development community through workshops and studies. Technology development typically is managed by potential end-users of that technology to encourage future adoption in a mission. Finally, graduating technology capabilities are widely publicized to the aerospace community to make project managers fully aware of new technological capabilities.

  Infusion during planning takes several forms. For long range planning, ESE technologists support the development of ESE strategic palnning and roadmapping. For nearer term planning, ESE technologists support various science working groups and assist in formulating science approaches that can incorporate anticipate technology developments. In the nearest term ESE supports studies which can indicate the potential risks and payoffs of inclusion of technology for projectds in formulation.

  During the technology development, infusion is encouraged by assigning management of technology development tasks to the technologically appropriate NASA Centers. By moving the direct technology management out to the potential end users community, ESE provides cognizance and familiarization with the given technology, technology ownership, and a link for potential infusion into applications for that technology.

  Infusion activities for graduating technologies are focused on educating potential users about the capability. This education takes several forms, from public forums that highlight advancements (an annual Earth Science Technology Conference , presentations in public proceedings such as IGARRS), reporting (Journal papers, conference proceedings, Annual ESTO Report), and finally by direct ESTO representation to projects in formulation by technologists assigned to define the technology alternatives and to encourage their adoption.

These technology management strategies are integrated in a synergistic way, guided by the overall Enterprise strategy as shown in Figure 2.

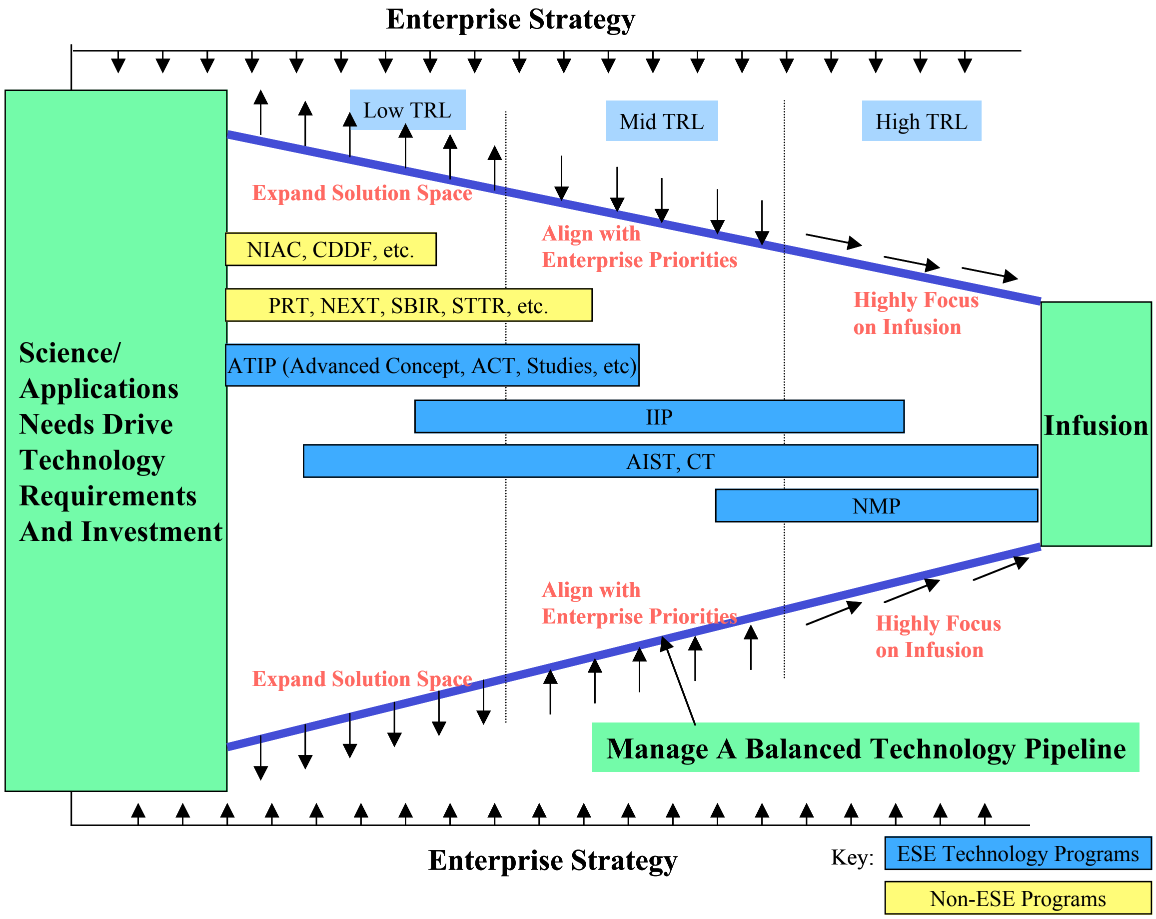

Figure 2. Guided by the overall Enterprise strategy and driven by the science and applications needs, ESE Technology Program collaborates and partners with other technology programs and manages the technology investment in a balanced way to meet the near-, mid-, and long-term Enterprise capability needs

Technology Thrust Areas focus the ESE investments

Applying the strategy outlined above, the specific technology focus investment areas follow directly from needs expressed in the six ESE themes and their coupling to the twenty-three ESE questions (Figure 3). Enabling technologies have been identified within each theme and have been divided into two major thrusts – observing technologies and information technologies.

THEME	QUESTION	TECHNOLOGY
WATER	Precipitation, evaporation & cycling of water changing? (V1)	Precip Radar, Radiometer, Large Antenna, Very Low Freq. Radar, On-board Processing
WEATHER	Weather forecasting improvement? (P1)	Real-time Data Assimilation, Interoperable Data Models
SOLID EARTH	Motions of Earth & interior processes? (V6)	Gravity Gradiometer, Magnetometer
	Surface transformation? (F3)	Hyperspectral Imaging, Thermal, Ob-board Processing/Data Compression/Storage, Fusion
CARBON	Global ecosystems changing? (V3)	Imaging Spectroscopy, Dual Freq. Radar, Data Mining, Fusion
	Changes in land cover & land use? (F2)	Imaging Spectrometry, Hyperspectral, Low Freq. Radar, Data Mining, Fusion
	Ecosystem responses & affects on global carbon cycle? (R2)	Active Optical, Data Distribution, Mining, Fusion
	Consequences in land cover & land use? (C2)	Hyperspectral, Topography, Data Mining, Fusion
	Future concentrations of carbon dioxide and methane? (P5)	Carbon Cycle Modeling, Data Visualization
CLIMATE	Global ocean circulation varying? (V2)	Precision Altimetry, Vector Wind, Active/Passive Microwave
	Ice cover mass changing? (V5)	Dual Freq. Radar, Lidar Altimetry, Data Mining
	Clouds & surface hydrological processes on climate? (R1)	Radiometry, SAR, Interferometric SAR, On-board Processing/Data Compression/Storage
	Changes in global ocean circulation?(R3)	SAR, On-board Processing/Data Compression/Storage, Mining, Visualization
	Sea level affected by climate change? (R5)	SAR Interferometry, GPS, Data Visualization
	Weather variation related to climate variation? (C1)	Precip Radar, Data Mining, Fusion
	Coastal region change? (C3)	Multispectral Radiometry, Data Mining
	Transient climate variations? (P2)	Climate Modeling, Data Visualization
	Trends in long-term climate? (P3)	Long-term Climate Modeling, Data Mining, Fusion
ATMOSPHERIC COMPOSITION	Stratospheric ozone changing? (V4)	UV-IR Spectrography & Imaging, Lidar
	Atmospheric constituents & solar radiation on climate? (F1)	Active Optical, Interferometry, Interoperable Data Models
	Stratospheric trace constituent responses? (R4)	UV-IR Spectrography & Imaging, Spectrometry, On-board Processing/Data Compression/Storage
	Pollution effects? (R6)	Lidar, Passive Radiometry, Data Visualization
	Future atmospheric chemical impacts? (P4)	Atmospheric Constituent Modeling

Figure 3. Technology Needs by Science Theme

Observing Technology investments offer expanded capability while reducing cost of Earth observations.

Advanced instrument technologies offer new and more comprehensive remote and in-situ measurements of the Earth's land, ocean, and atmosphere. They provide better spatial, spectral, and temporal resolution while reducing volume, mass, power, development cost and time. ESE focus technology investments (Figure 4) cover the entire electromagnetic spectrum, including both passive and active sensors. These investments will enable measurements from new vantage points in space, such as the geostationary orbit or libration points, which offer continuous and global Earth coverage and will allow smaller, lower cost launch vehicles for capabilities in Low Earth orbit.

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Observational Technology Area	***Primary challenges***
Passive imaging systems	Large format detectors from .2µm to 15µm
Imaging spectrometery	Fast, compact optics and grating systems

	to allow major reduction in mass, cost and complexity; on-board calibration and data processing to reduce downlink requirements
Active optical imaging systems	Lightweight, high power, cooled, reliable laser systems for lidar applications;
Active microwave	Large, lightweight, deployable antenna system with distributed T/R modules; Modular, compact, high efficiency rf and digital subsystems for affordability; On-board integrated processors to reduce data downlink requirements
Passive microwave, from 1 Ghz to 2.3 THz	Large deployable antennas (to 30 m dia), both full aperture and synthetic aperture; multi-frequency, multi-pol feed systems; low cost and mass mmic-based receivers (1-350 GHz) in arrays to enable imaging systems with up to hundreds of receivers; cryo heterodyne receivers (300 GHz – 2.3 Thz) ; signal distribution systems for large synthetic arrays
Formation flying to achieve ultra-large sparce baselines	Deployment of large antennas (100 m class) for SAR systems; precision ranging, dynamic and kinematic control to allow INSAR observations from distributed platforms, including beam forming; autonomous operation of constellation
Quantum device sensors	Provide atom manipulation and laser cooling capabilities for advanced quantum interference sensing capabilities; develop inversion models to allow extraction of detailed subsurface gravitational features.

Figure 4. Key observing technology critical challenges and technology investment foci

Information Technology investments leverage commercial investments and apply them to enable future Earth Science Missions.

Advanced information technology investments are motivated by the vast amounts of observation data from space-borne sensors and the associated practical difficulties of acquiring, processing, storing, and delivering data products. The investment portfolio addresses the end-to-end information system, beginning with observation, on-board data handling and computing, transmission to ground, storage, data mining and finally to product distribution.

Future remote sensing architectures will employ large numbers of networked sensors that are frequency-agile and capable of multi-scene observations from different space vantage points, and are capable of real-time, autonomous adaptive tasking to enable the integrated observing system of the future. Advances are required in robust information technology architectures with miniaturized and programmable components, high-speed and programmable on-board data processing, autonomy, and high capability IP data distribution.

The ongoing information technology revolution has been funded and driven mainly by worldwide commercial industry. It is expected that the information technology industry will continue providing many breakthrough technology solutions. NASA will leverage this broad industry base and focus its information technology investments (Figure 5) on developing or adapting state-of-art technologies for the space-based applications and for utilities that are unique to the generation and application of Earth system science understanding and information products.

Information technology area	***Primary challenges***
On-board Data Processing	Apply and adapt commercial technology to achieve fault-tolerant, high throughput on-board processors
Space-based Communications	Enable sensorweb concept through development of protocols for dynamic space links and for dynamic space link capacity; integration of mobile terminals and space comm. gateways; Development of secure key management protocols;
High-end Computing	Enable high fidelity (both temporal and spatial) models of the earth processes by developing next-generation discipline models; Earth Science system frameworks and coupled models; data assimilation; and by optimizing model performance for newly developing computing platforms
Information synthesis (data mining, fusion, manipulation, visualization)	Derive information from extremely large, multimission data sets; provide rapid, portable access and dissemination of data.
Mission Automation	Develop real-time event detection and image recognition; self-tending spacecraft and instruments; high-level command language for sensor re-targeting
Data access and dissemination	Provide access to extremely large data sets with ease: provide extraction of small sized data subsets and geolocation references to multi-mission data sets.

Figure 5. Key information technology critical challenges and technology investment foci